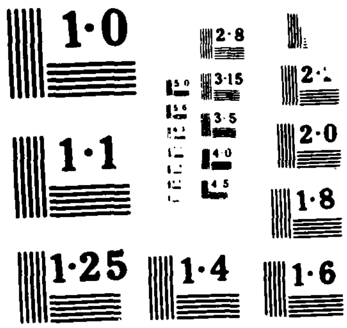
AD-A191 009 ENHANCED BACKSCATTERING FROM ROUGH SURFACES(U) IMPERIAL COLL OF SCIENCE AND TECHNOLOGY LONDON (ENGLAND) J C DAINTY 09 OCT 87 DAJA45-87-C-0039 1/1

UNCLASSIFIED F/G 20/6 NL


1·0
2·8
3·15
3·5
2·0
1·1
4·0
1·8
1·25
1·4
1·6

2

ENHANCED BACKSCATTERING FROM ROUGH SURFACES

Principal Investigator: J C Dainty

Contractor: Imperial College

Contract No: DAJA45-87-C-0039

1st Periodic Report

July 1987 - August 1988

(Report Date: 9th October 1987)

"The research reported in this document has been made possible through the support and sponsorship of the US Government through its European Research Office of the US Army. ~~The report is intended only for the internal management use of the Contractor and the US Government~~."

1. PROGRESS DURING REPORTING PERIOD

Further photoresist surfaces have been prepared, but are not yet fully characterised by Talysurf and optical microscopy. Results of infra-red (10.6 microns) scattering for I_{ss}, I_{sp}, I_{pp} and I_{ps} from one of these surfaces are given overleaf. This is the first really conclusive piece of evidence that we are getting significantly different behaviour for s and p incident polarisations. Curves are given for angles of incidence of 0° and 30°. Note the tendency of the cross-polarised return to maximise towards backscatter and the quite different shapes of the I_{ss} and I_{pp} curves at 30° angle of incidence. Although the rms surface height (approx 1 micron) is very much less than one wavelength, the Rayleigh parameter $R = 4\pi\sigma_h/\lambda$ is not small in the perturbation sense.

2. Research Plans

Andrew Sant (research assistant employed on Contract from 1 October 1987) will have three initial goals: (i) to prepare a computer-based (Apple MAC) bibliography on enhanced backscattering (ii) to update the equipment to include wavelengths of 1.15 and 3.39 microns and (iii) to prepare some two dimensional surfaces (i.e. random gratings). The motivation for this latter task is our growing realisation, notwithstanding Bahar's work, that the full three dimensional theory is unlikely to be feasible in the immediate future. However, rigorous two dimensional (numerical) solutions are available now.

3. Administrative Actions

The research assistant post was offered to Andrew Sant, who recently got a First Class Honours BSc in Physics from Imperial College. He has accepted and joined us on October 1st.

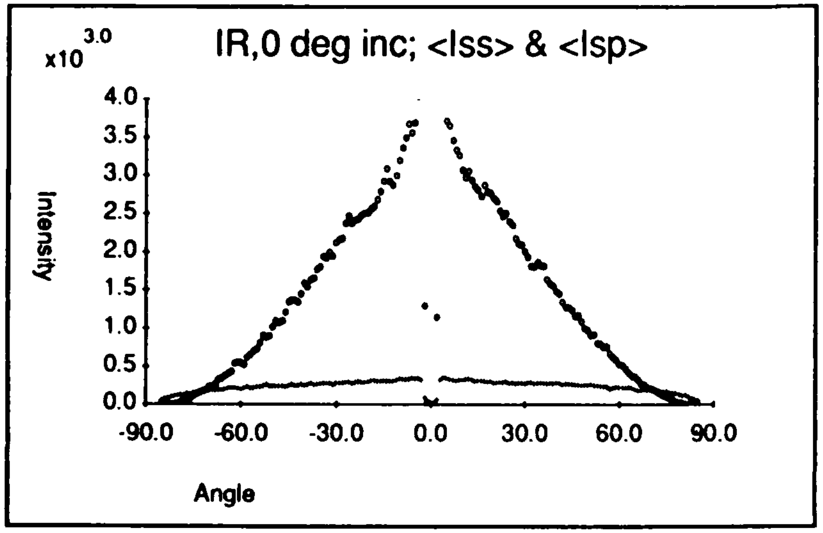
4. Other

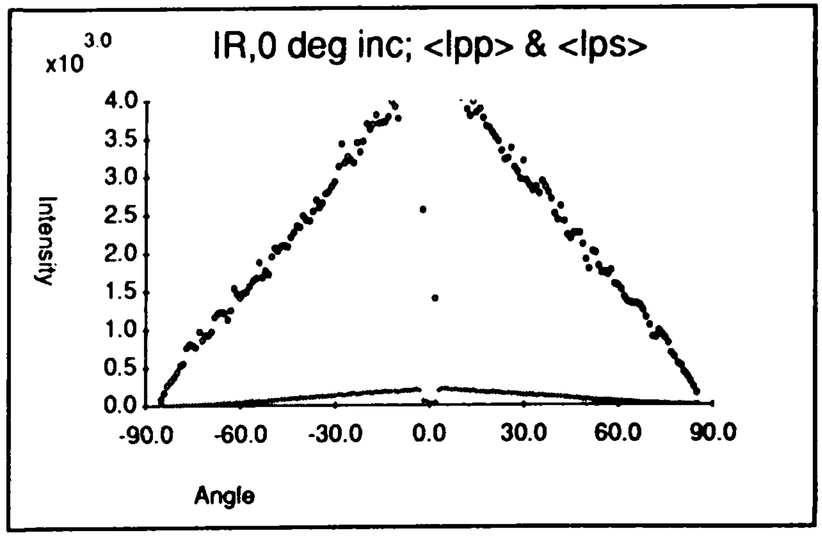
M-J Kim presented a paper at the General Assembly of the International Commission for Optics, in Quebec, Canada, August 24-28 1987 (attached).

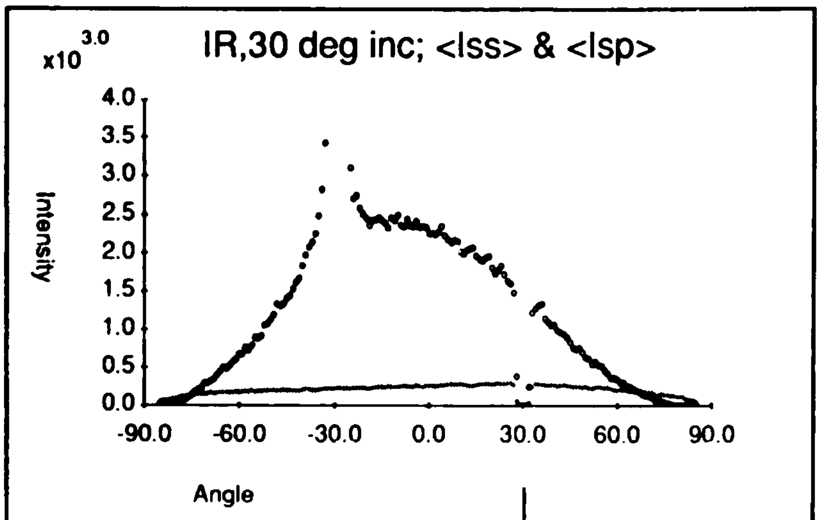
per form 50

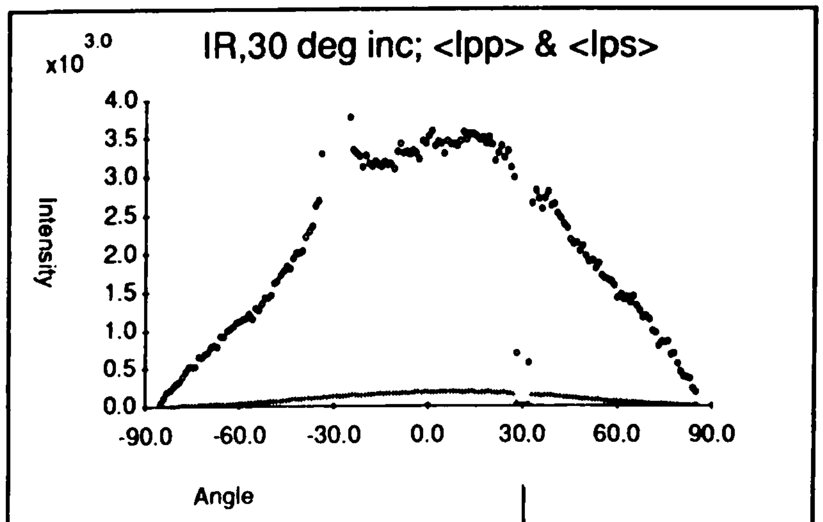
A1

Surface parameters; R~1.2, ka~2.1









backscatter

Measurements of Light Scattering by Randomly Rough Surfaces of Known Statistics

A. S. Harley, M-J. Kim and J. C. Dainty
Blackett Laboratory, Imperial College of Science and Technology
London, SW7 2BZ, UK

Over the past few decades, a very large number of theoretical studies of the scattering of electromagnetic waves by rough surfaces have been published[1]. Unfortunately, no satisfactory theory is available for surfaces of arbitrary statistical properties. Only solutions for certain surfaces and scattering geometries are available, e.g. Kirchhoff or physical optics theory (after Beckmann[2]) for surfaces of very low slope and long correlation length relative to the wavelength. Although experimental studies have been made, the surface statistics in the experiments have rarely been matched to the assumptions of theory, rendering the results of little value for verifying theories. The aim of the present study is to measure the angular distribution of light scattered by surfaces that are very well characterised and whose statistics closely approximate the theoretical assumptions.

Four classes of surfaces have been studied and they are distinguished by order-of-magnitude differences in their statistics. Three of these classes have surface profiles which approximate a Gaussian process, with Rayleigh parameter (for normal incidence) $R = (4\pi/\lambda)\sigma_h$ and Gaussian correlation function with parameter $a = (\frac{2\pi}{\lambda})\xi$; σ_h^2 and ξ are surface height variance and $1/e$ correlation length respectively. The classes are: (i)$R, a \gg 1$ but $R/a \ll 1$, (ii)$R \leq 1$, a arbitrary, but $R/a \ll 1$ and (iii)R, a arbitrary but $R/a \sim 1$. These surfaces are specially fabricated by exposing photoresist to laser speckle patterns with well-defined statistical properties and coating them with gold after development[3]. The fourth class are multiscale fractal surfaces and are characterised by an inverse spectral exponent ν and a surface scale, the topothesy, L.

Surfaces in classes (i) and (ii) have low slopes: physical optics is valid for class (i) surfaces, where the correlation parameter, $a \gg 1$, and physical optics or perturbation theory is applicable to the slightly rough surfaces of class (ii) for the cases $a \gg 1$ and $a \leq 1$ respectively. Figure 1 compares an experimental result for class (ii) surfaces in which $R = 1.65$, $a = 18.5(\pm 10\%)$ with the physical optics result for the same value of R and a fitted value of $a = 19.5$. Agreement with the physical optics theory in this particular régime has also been noted by Mendez and O'Donnell[5], whose work for this case was carried out in the infrared ($\lambda = 10.6\mu m$), in contrast to the present work ($\lambda = 0.633\mu m$).

Surfaces in class (iii) have high slopes and have been shown to exhibit enhanced backscattering[4-6]. Figures 2(a) and (b) show the angular distribution of scattered light for an angle of incidence of 5° from the normal (the first suffix denotes the polarisation of the incident beam, the second that of the scattered beam), for a surface in which $R \approx 30$, $a \approx 30$. No satisfactory exact theory for explaining enhanced backscattering has yet been given, but a qualitative, geometrical explanation incorporating retroreflection and reciprocity has been suggested[5,6]. Currently under investigation is an approach which reduces to calculating the scattering of deterministic shapes, randomly distributed on a plane to simulate the surface.

Figure 3 compares the mean angular distribution of light scattered by an approximately fractal surface (ground glass, in transmission) with inverse exponent $\nu \approx 1.2$ and topothesy $L \approx .15\mu m$, with the physical optics prediction[7]. Because of the non-differentiable nature of these surfaces, physical optics cannot strictly be applied but in practice, the amount of scattering power in spatial scales around the wavelength determines whether it may be used. These surfaces are interesting as they commonly appear as the result of natural or abrasive processes.

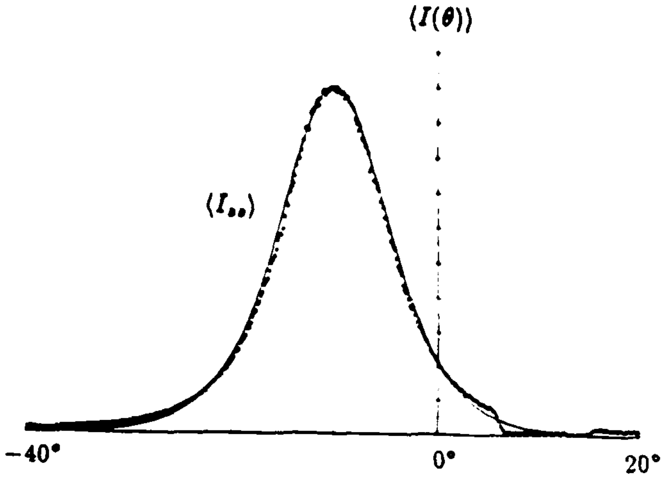


Figure 1

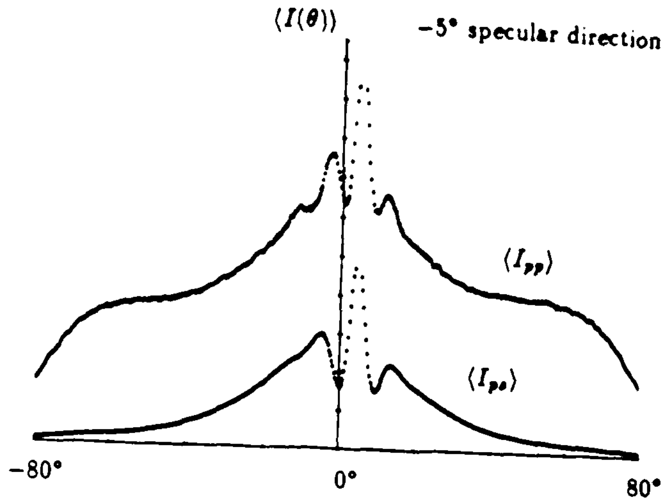


Figure 2(a)

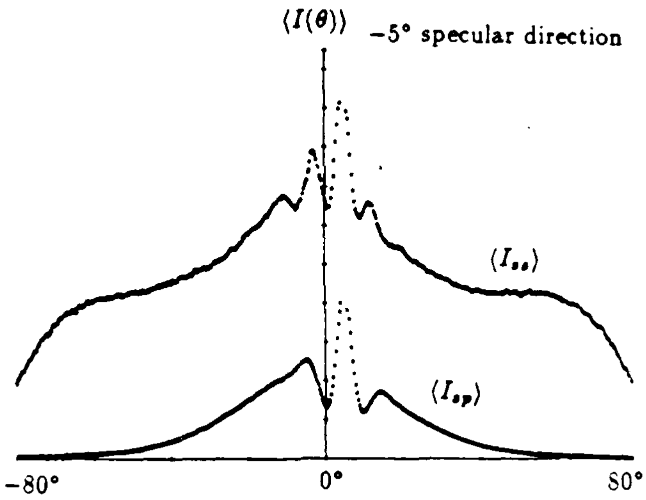


Figure 2(b)

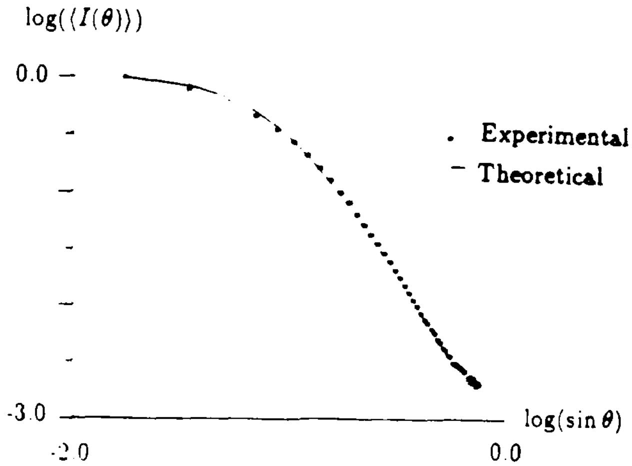


Figure 3

REFERENCES

1. G. S. Brown and J. A. De Santo, *Progress in Optics* Vol. 23, Ed. E. Wolf, Elsevier.
2. P. Beckmann and A. Spizzichino, *The Scattering of Electromagnetic Waves from Rough Surfaces*, Pergamon, New York (1963).
3. P. F. Gray, *Optica Acta* **25**, 765–775 (1978).
4. A. S. Harley, E. R. Mendez and K. A. O'Donnell, conference digest of *Optical and Millimeter Wave Propagation and Scattering in the Atmosphere*, Florence (1986).
5. E. R. Mendez and K. A. O'Donnell, *Opt. Comm.* **61**, 91–95 (1987).
6. K. A. O'Donnell and E. R. Mendez, *J. Opt. Soc. Am.*, in press.
7. D. L. Jordan, R.C. Hollins and E. Jakeman, *Appl. Phys.* **B31**, 179–186 (1983).

ACKNOWLEDGEMENTS

We are grateful to D.Gale for assistance in the characterisation of the surfaces and to the U.K. Science and Engineering Research Council (GR/E 40910) and U.S. Army for financial support.

END
DATE
FILMED
5-88
DTIC